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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

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Reciprocating Steam Engines

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Lubrication of Marine Steam Propulsive Machinery

Reciprocating Steam Engines

THE history and the development of marine steam engineering has been one of absorbing interest. Its progress has been positive and clearly defined ever since the advent of the historic "Clermont." The evolution of the steam engine dates back to 1689 when Thomas Savery raised water by filling a vessel with steam and condensing the steam by playing cold water upon the outer surface of the container. The vacuum sucked the water up and it was displaced by another charge of steam.

Desaguliers, Pain, Newcomen and Potter, respectively contributed to the development of the steam engine, in the years that followed, up to 1763 when James Watt realizing the amount of heat that it took to warm up the chilled cylinder for the succeeding stroke added the separate condenser. Not only was the fuel consumption greatly reduced thereby, but the way was cleared for the improvements that made the engine a practical prime mover.

After Watt's invention of the separate condenser, many years elapsed before the next important step—the introduction of the compounded steam engine, around the year 1854. A decade or two later the old box boiler was replaced by the now highly appreciated circular Scotch return tube boiler, supplying steam to two-cylinder compound engines at about 60 pounds pressure. It was not then found profitable to carry more than about 25 inches of vacuum.

In the early days trunk-piston steam engines found favor as a means of eliminating the objectionable feature of the connecting rod for the propulsion of steamships of limited beam. Owing to the difficulty of keeping the trunks steam-tight when higher pressures were gradually introduced this type of piston was later abandoned. In those days horizontal machinery was not uncommon on board seagoing ships but gradually gave way in both the Navy and the mercantile service to the vertical type engines for screw ships. In some paddle steamers for river and coast service, of which there were many, the oscillating engine was built; but the diagonal engine was more common.

Where paddle wheel propulsion was employed, the position of the paddle shaft, being above the water-line, necessitated vertical or inclined steam engines. With the advent of the screw propeller it became possible, owing to the low position of the propeller shaft, to place the whole of the propelling machinery, below the waterline. Particularly to warships of that day was this feature important as it afforded some protection from hostile damage. Due to difficulties experienced in connection with the working of the cylinders and pistons, which were susceptible to excessive wear on their lower surfaces, and because of the general lack of accessibility which more than offset the gain in head-room, horizontal engines gradually

passed out of favor in place of the vertical engines.

About the year 1875, the first triple-expansion, three-crank engines made their appearance together with 125 and 150-pound pressure corrugated furnace boilers. Soon thereafter quadruple-expansion engines, using pressures of 160 to 200 pounds, or even higher, became common, with improved economy in fuel; but the lower limit of pressure at the condenser was still little altered.

Importance of Lubrication

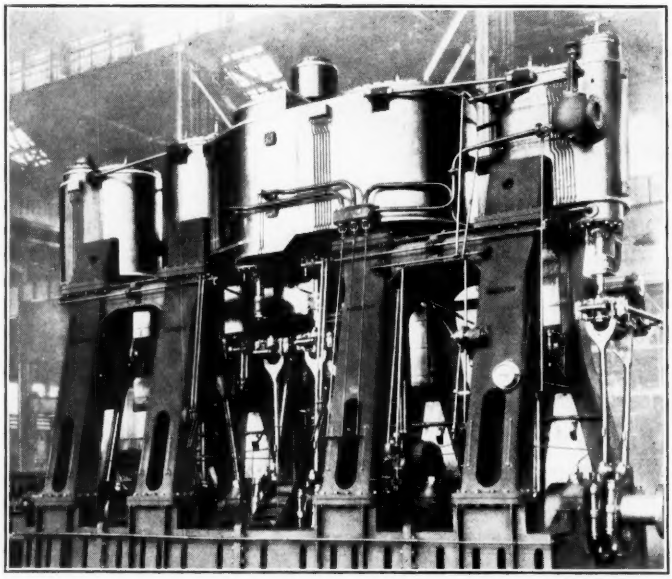
The object of marine lubrication is both to reduce friction and to prevent excessive temperatures. The true value of a lubricant, whether it be applied to a reciprocating engine, a steam turbine and its gears, or a Diesel engine, depends upon its efficiency in reducing friction, its durability under wear and adverse mechanical conditions, its freedom from acids and grit, from liability to gum, and its physical condition when subjected to change in temperature.

The competent marine engineer of today is seriously interested in the science of lubrication. He thoroughly realizes the overwhelming importance of individual quality and efficiency of lubricating oil and the disastrous consequences which may result from the failure of an improper lubricant to perform its duty.

For many years lubrication was looked upon as merely a process of putting on oil without regard to quantity or quality of the lubricant. If a bearing receiving plenty of oil ran hot, it was usually believed the cause was due to some mechanical defect, whereas in numerous cases the actual cause was the use of an improper lubricant.

If all the oil used on marine engines accomplished its function without waste, comparatively small quantities would be necessary. When fed by hand the oil film will cling to bearings and continue to perform its function for a limited period. Oiling at regular intervals should be the rule of the staff. With an automatic feed, carefully regulated, the consumption can be kept low while accomplishing a maximum effect. In circulating systems where high quality oils are repeatedly purified by mechanical or filtration methods, they will last indefinitely, requiring but small quantities for replacement. With the idea in mind of adequate lubrication without waste, the highest grade lubricants for given uses become the most economical.

The first cost of a lubricant is of comparatively minor importance, when the effect of lubrication on machinery is considered. The slightest delay in port made necessary by burned out bearings or any other cause due to faulty lubrication rapidly overtops the lubricating oil bill covering a long period.



Courtesy of The Hooven, Owens, Rentschler Company

Fig. 1—A modern quadruple-expansion marine reciprocating engine of the "Tamiahua" type, $\frac{27\frac{1}{2}'' \times 40'' \times 59'' \times 86''}{54''}$ developing 4200 I.H.P. at 75 R.P.M. with a boiler pressure of 210 lbs. This illustration clearly shows the oiling system supplying the Stevenson link motion and the eccentrics as well as the oil-manifold boxes for distributing the lubricant to the other operating machinery units. Note the assistant cylinder mounted on top of the low pressure valve chest.

RECIPROCATING STEAM ENGINES

One of the most interesting and important advances in modern marine engineering practice has been the increase in boiler pressures and steam temperatures which have taken place the past few years. No one can question the important part which triple and quadruple-expansion reciprocating steam engines have played in the history of marine propulsion. For generations they have been the backbone of ship propelling machinery. In contrast the steam turbine and the Diesel engine are veritable youngsters. The reciprocating steam engine is more useful at high pressures than at extremely low pressures, and mechanically it is understood by all marine operating personnel.

Before the advent of mineral oils, marine engines were lubricated with sperm or whale oil, by a vegetable oil such as rape seed or olive oil, or in some cases with lard oil. One excellent reason for the abolition of animal oils, especially lard oil, was the bad stench which

it created in the engine room bilges. Animal oils were also liable to clog up the distributing pipes unless they were cleaned out frequently. Irrespective of these fundamental defects possessed by animal and vegetable lubricants, the price would make them commercially impossible as lubricants for this very extensive class of service today.

In the lubrication of marine reciprocating engines a lather is essential when working with water. The animal and vegetable oils formerly applied, all formed such a lather on the guides and in the bearings in the presence of water. It was found that the resultant film did not wash from the surfaces as rapidly as straight mineral oil. Later developments established the practice of compounding marine oils on the basis of a mineral stock containing from 10 to 20 per cent of vegetable or animal oil.

REQUIREMENTS OF A LUBRICANT

Irrespective of the price, or any specifications that may be used, a marine lubricant to be really efficient must meet the following requirements:

(1) It must be of sufficient body to keep the bearing surfaces apart at working temperatures.

(2) It must possess lubrication qualities that will reduce friction to a minimum.

(3) It must remain fluid at the lowest temperatures that are met with under ordinary service conditions.

(4) It must meet service requirements as to durability, resistance to steam, etc.

(5) It must contain no impurities which would corrode or pit the bearing surfaces.

(6) It must have no tendency to decompose or form deposits which may accumulate in the oiling system.

(7) It must be of sufficient capillarity to feed evenly, with little change in this respect when encountering natural changes in temperatures.

These essentials as a guide for selection apply with equal importance to practically every class of marine machinery, be it steam reciprocating engines, turbines or Diesels. There can be no compromise on quality, nor neglect of the necessary details of care, if really efficient lubricating service is to be secured. There has never been an instance where skimping on lubrication quality did not prove to be an expensive policy or experiment. There is very little money difference between the initial cost of reliable, high-grade lubricants and those physically unsuited for the work. There is, however, a much greater difference when comparative service results are analyzed. Any sacrifice in quality to accomplish a tentative saving will invariably result in the ship owner or operator paying a high increase over his just lubrication costs as a penalty for his poor judgment.

CLASSIFICATION OF BEARINGS

Bearings may be classed generally under two divisions, journal bearings and thrust bearings. Journal bearings are cylindrical and the load is carried at right angles to the axis of the bearing. When the load is carried or applied in a line parallel to the axis, it is called a thrust bearing. In addition, there is a sub-classification consisting of those bearings which permit moving parts to slide over them. The crosshead guides of a reciprocating engine are an example of this type which are known as sliding contact bearings.

From a marine lubrication standpoint, it is necessary to differentiate further as there are a variety of conditions presented under each of the main classes. These include:

(1) Dead-running journals with uniform load always applied in one direction and a constant journal velocity.

(2) Bearings where the load is constantly shifting from one side of the bearing to the other, and where the load is not always uniform, such as the crankpins and main bearings.

(3) Bearings where the motion is reversible.

(4) Bearings subjected to heat other than that generated by bearing friction, such as hot water or steam leakage.

PRINCIPLES OF BEARING LUBRICATION

Application of the lubricant to the bearings is a subject which has always attracted considerable attention. It seems now to be very well established that the following principles should govern:

(1) The lubricant should, wherever possible, be led into the bearing at a point which is under the lowest pressure.

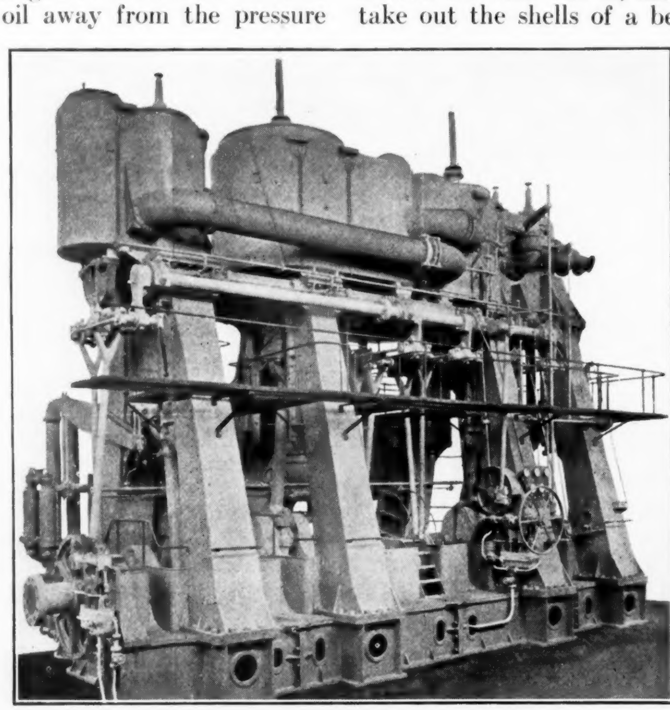
(2) The continuity of the oil film, where it is under the greatest pressure, should not be interrupted by oil channels or grooves.

(3) The lubricant should be prevented, as far as possible, from escaping at those points which are under the greatest pressure.

In the case of main bearings, etc., these principles are very commonly violated, and in fact it can hardly be said that practice has as yet come to act upon them, though their correctness seems to have been well demonstrated. According to these principles the oil for the main pillow block bearings should be introduced near the division between the upper and lower brasses, and the oil grooves in the metal of the bearing at the top and bottom should be

omitted. Similarly for the crank pin and other cylindrical journals, the oil should be admitted at those points where there is the least pressure, and at the points where the pressure is greatest the bearing surfaces should be smooth and not interrupted by grooves, scores, or oil channels of any kind whatever. Where such practice is not adhered to, the grooves break the oil film and conduct the oil away from the pressure area, frequently rendering proper lubrication impossible.

The division between the bearing halves of cylindrical bearings is usually located at the sides of the bearings. At this point the pressures are at a minimum. The bearing metal surface should be scraped or eased away near these joints, and a chamfer should be cut on the edge of the bearing metal. In order to prevent the escape of oil, grooves should not be carried closer than about three-quarters of an inch from the bearing end. It is also a good practice to fit the distance pieces and shims or liners closely to the journal near the ends of the bearing, cutting away the middle portion to agree with the outline of the chamfers.



Courtesy of Richardson, Westgarth & Co., Ltd.

Fig. 2—A favorite type of merchant marine engine is this 4800 I.H.P. $\frac{27\frac{1}{2}'' \times 37\frac{3}{4}'' \times 55'' \times 84''}{60''}$ quadruple-expansion job with inside H.P. piston valve, first and second M.P. balanced slide valves, and L.P. double ported slide valve. Note that tail rods are employed on the 58″ and 84″ diameter cylinders, and double cross-head guides are used. Operating platform and maneuvering gear is on the right, and the position of the rocker shaft and its relation to the Stevenson valve gear is clearly indicated. An Edwards air pump and bilge pumps are driven off the first M.P. engine through attachment to its crosshead.

RECORDS OF BEARING WEAR IMPORTANT

It is of distinct advantage to a marine engineer to keep a record of wear of each individual bearing as these data are often of future aid. The wear may be charted in a diagram and comparison made of the rates of wear between different bearings and, also, in the case of multi-screw vessels, between different engines. It will be particularly advantageous to refer to such a set of figures in the event of a hot bearing.

There are many reasons for such a condition arising. Among the most common causes of hot bearings may be cited misalignment of the bearing due to any reason whatever, the passing of impurities such as grit or emery into the bearing, the lubricating oil may be unsuited, or though originally of good quality, it may have become gummy or otherwise deteriorated.

In the case of a bearing running hot, its oil grooves and oil holes frequently fill up with melted babbitt. It is, therefore, advisable to take out the shells of a bearing that has run hot and inspect the oil grooves and oil holes, to prevent repetition of trouble.

LUBRICATING SYSTEMS

In the successful operation of modern marine machinery the judicious and economical distribution of the lubricating materials necessary to reduce the friction of the moving parts, forms an important factor. This is a subject upon which there has existed as great a diversity of opinion as can be found anywhere among seagoing engineers, who have firmly established individual ideas as to the kind of lubricants to be used and the methods of applying them.

The average oiler may be prone to place too much reliance upon self-feeding devices, and as a result, become lax in his attention to the journals. If he is compelled to oil by hand at all speeds, he will be much more proficient at full speed when the machinery requires the greatest care.

The advent of the modern multiple-expansion engines has caused greater attention to be paid by designers to automatic devices for distributing lubricants. The advantages of any mechanical oiling system consist in the certainty and regularity of operation which may be assured with the minimum of time and attention on the part of the operating staff.

Lubrication systems on reciprocating steam engines may be divided into two classes:

(1) As applying to external bearings which

are not enclosed within the parts of the engine which hold steam.

(2) As designed for internal bearings such as the piston, cylinder, valves, and stuffing boxes.

In reciprocating engines where the problem is largely one of external lubrication, there is good opportunity for conserving oil through a careful study of oiling methods. From the engine to the propeller, external lubrication for the prevention of friction losses is necessary at the crossheads and guides, valve gears, eccentrics, main bearings, crank pins, thrust bearings, and line shaft bearings. The problem of maintaining bearing adjustments, piston clearances, spring tension and the like at exactly the correct point to prevent overheating and, at the same time, eliminate pounding are too well understood to require comment. Suffice to say that the maintenance of shaft alignment and careful adjustment of moving parts is the first duty of the staff.

In connection with hand oiling as well as with lubrication systems, the question of economy in the use of lubricants resolves itself into a personal equation to a large extent. Where one oiler, by vigilance and good judgment, can keep an engine running cool with a certain allowance of oil, another may use twice as much with no better results. With the adoption of economical methods and a strict supervision of the engine room force by the engineer-on-watch, it is safe to say there are but few vessels where a saving could not be accomplished.

EXTERNAL LUBRICATION

External lubrication to reduce friction and wear to a minimum and to keep bearing temperatures within reasonable limits, may be carried out by hand, oil cups, wick feed, gravity, forced-feed, or a combination of these systems. The modern gravity wick feed systems, where the siphoning effect of strands of worsted yarn is utilized, can be classed as mechanical lubrication. The distributing centers are light cast brass boxes, from which the oil is taken by brass piping as directly as possible to the various bearings, each having its own independent pipe and set of connections.

Each cylinder is provided with its own manifold oil box, placed at a point higher than any bearing to be reached by the oil and within reach of the grating. Each box is fitted with a cover, and has a capacity sufficient to last several hours without refilling. These oil boxes are provided with sight feed cups with protected glass tubes, from which pipes lead to wipers on the moving parts, or to tubes in the bearings and guides. Union joints are fitted where necessary, so that the oil pipes may be quickly taken down and cleaned. With few exceptions the oil for the various moving parts is supplied from this box.

The ends of the pipes in the oil box should extend above the normal oil level in the manifold, within about two inches of the top. The feed is regulated by worsted yarn wicks which give a regular and reliable supply of oil and act as automatic filters and strainers. They are fitted with a lead sinker on one end and a twisted wire on the other. The sinker ends are submerged in the oil contents of the manifold, the wires being inserted in the feed pipes. Oil travels up the wicks by capillary action and siphons over, to subsequently drip into the pipes and be led to the various parts.

As with other methods of lubrication, the rate of oil feed should be maintained practically constant and only in sufficient volume to lubricate the bearings adequately. This is, however, seldom if ever accomplished. When the oil manifold box is full, the oil flows freely, dropping off as the level falls. If at the low levels the bearings are receiving sufficient oil, then when the rate of flow increases with higher levels the conclusion must follow that oil is being wasted. In the great majority of cases wick feeders supply more oil than is necessary assuming high grade lubricants are employed.

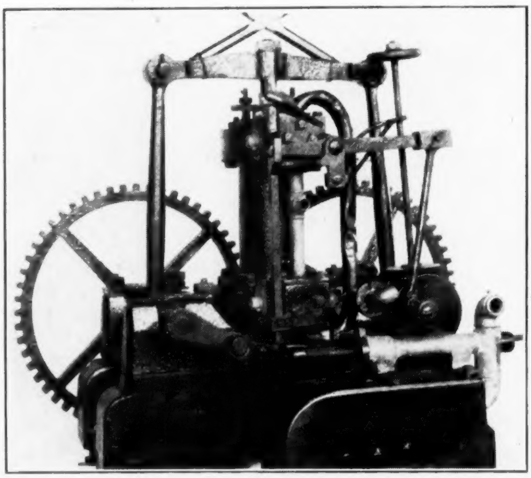
The possibility of changing the number of strands in a wick and of determining the proper length wick to give the correct flow and avoid fluctuation is of great importance. Tests have determined that the lower end of the wick adjusted at a distance of about two inches below the lowest oil level will increase the uniformity of flow at all levels. Greater wick lengths than this do not alter the effect appreciably, while if the wick is much shorter there will be an excessive variation of oil flow between fillings. The study of wick feeders can be carried to the point of taking out the strands of the wick, one at a time, watching the effect on the bearing temperatures and, when the bearing begins to overheat, replace one strand of wick for safety. Once the proper balance is obtained the flow will practically be unaltered if the same quality lubricant is continuously used.

As dirt filtered from the oil causes a wick to become gummy and lose its filtering effect, wicks should be stripped once every watch when the engine is in operation to guard against cessation of lubrication. The entire wick should never be too heavy, and judgment must be used in deciding on the number of strands suitable. Were too many strands used, capillary action would be retarded and if the wick were not regularly stripped, lubrication might even be discontinued. The wicks should, of course, always be removed from the tubes when the machinery is secured to prevent a waste of oil.

As a safeguard in wick feed lubrication hand oiling is generally resorted to whenever the oiler makes his rounds, as well as when first warming up the machinery. It must be borne in mind that overheating of marine engine bearings is a far more serious matter than it would be in stationary practice.

OBJECT OF COMPOUNDING

For wick and hand feed lubrication, marine engine oil should have a viscosity of about 650 seconds Saybolt Universal at 100 degrees Fahr.; it is today generally compounded with blown rape seed oil in varying percentages up to 20 per cent which is generally considered best practice. The object in compounding mineral oils with blown rape seed oil is to impart to it desirable emulsifying qualities. After an oil is in an emulsified state, its viscosity is raised and its adhesive and cohesive qualities are greatly increased. In this condition the oil is able to resist successfully the washing effect of water, which is always present around a marine engine. Clinging tenaciously to the bearing surfaces, an emulsified oil acts also as a temperature indicator.



Courtesy Marine Engineering & Shipping Age

Fig. 3—The original twin-screw reciprocating rotative marine steam engine with a $4\frac{1}{2}''$ x $9''$ cylinder built by Colonel John Stevens of Hoboken, New Jersey in 1803. Recognizing the tendency of a single-screw propeller to turn a vessel, it was sought to overcome this by a twin-screw engine whose shafts revolved in reversed directions. This plan for working twin-screws by a single cylinder is the most simple that could be devised. The reaction of the connecting rods against each other at their junction with the piston rods acted as a parallel motion, or as slides would do, to keep the rod in alignment. Compare this toy with the illustration shown on the opposite page, depicting one of the most powerful marine reciprocating engines ever built in America.

METHODS OF APPLYING EXTERNAL LUBRICANTS

Crank Pins

Lubricant is furnished to the main crank pin by means of a pipe or pipes securely fastened to the connecting rod, and cups carried on the crosshead taking oil from a drip supplied by the oil box as described. The pipe runs down the side of the rod, or frequently inside if the rod is hollow, and connects with the oil duct leading through to the pin. Water service is provided to each of the main journal bearings as a safeguard in case of overheating. Due to water jacketing of these latter, they are subject to leaks—all of which, together with the general practice of washing down the engine with water, makes a compounded oil not only desirable but almost a necessity.

When the cream-like lather can be picked up by the fingers and it feels smooth and of a soapy nature, journals and bearings are running satisfactorily, but when the oil presents a dark brown or black appearance this can be taken as an indication that the pin or bearing is starting to heat up, and is an advance notice to the engineer that trouble is approaching.

Main Bearings

Main bearings are oiled by one or more wick cups delivering the oil at the points desired. The main bearings of some large reciprocating engines are provided with four oil inlets, leading in pairs to the chamfers at the bearing sides. A grease cup is also often provided as well as a hole through which the shaft may be felt by hand to ascertain any tendency of heating.

For the majority of important bearings, however, two oil inlets are deemed sufficient. These should preferably introduce the oil where the bearing pressure is lowest and be so located as to divide the length of the bearing into three approximately equal parts. When the oil inlets must be located within the pressure area, the cutting of circumferential oil grooves or channels through the oil inlets will facilitate the passage of the lubricating oil from the inlets to the chamfers cut at the sides of the bearing. These chamfers, acting as channels, permit the longitudinal distribution of the oil. The difficulty presented in supplying proper lubrication to a cylindrical bearing arises from the fact that the lubricant will not flow at right angles to the axis of the journal, but has a tendency to flow at various angles from such lines, and always toward the ends.

Crosshead Guides

The crosshead guides are provided with oil through pipes connected with holes at about the middle of each forward and backing guide. Oil grooves must be provided on the guides as no natural oil wedge formation exists on these flat surfaces as in the case of cylindrical bearings. These grooves have their edges rounded or cut with a thin bevel to assist the formation of an oil wedge. The crosshead guide surfaces have oil grooves cut in various forms, but the

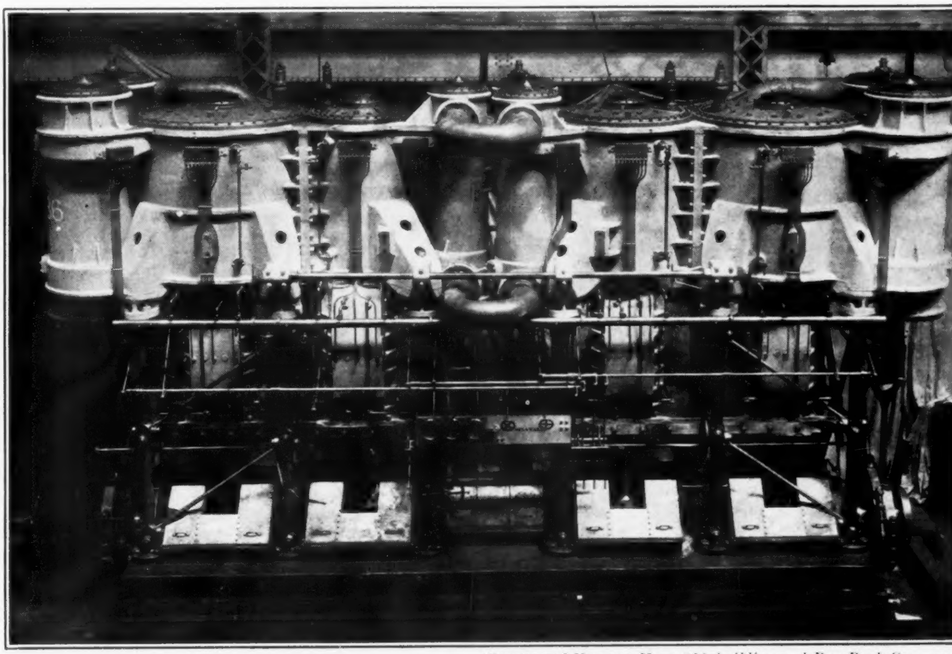
usual practice consists of grooving cut straight across the path of motion and spaced approximately twelve to fourteen inches apart.

It is important that such grooves do not extend to the sides of the guide surface in order to prevent the escape and wastage of oil. Guides are usually provided with internal cooling water pipes for dissipating the heat generated. It is also a practice to have combs attached to the crosshead which dip into cups mounted on the lower end of the guides. When the crank is on the bottom center the comb picks up a quantity of the compounded marine engine oil and water mixture in the cup and distributes it over the guide surface during the upward stroke.

Experienced marine engineers can judge the condition of guides by the appearance of the lubricant. The slides present a smooth cream colored appearance when the combs are evenly distributing the emulsified oil over the frictional surface and it is not necessary to feel the slides to determine their operating temperature. When dark spots begin to appear trouble is threatening and attention is required.

Eccentrics

The eccentric straps are fed from long narrow oil cups, receiving their oil through the drip pipes from the reservoir. The length of the cup is made such that some part of it is always under the drip in any position of the eccentric, which assures its always receiving an ample supply. The various other parts of the gear are similarly provided for lubrication either from a drip or a wiper, as may be more convenient. Eccentrics, as a rule, require a considerable amount of oil, but if they are so arranged that the lower part of the straps dip into fresh water in the drip pans, they will be found to run cool on a greatly reduced amount of oil, as compared to those which are not kept cool by water. These eccentric pans or water troughs should be cleaned at frequent intervals.



Courtesy of Newport News Shipbuilding and Dry Dock Company

Fig. 4—One of the largest four-cylinder $\frac{38\frac{1}{2}'' \times 57'' \times 76'' \times 76''}{48''}$ triple expansion, direct-acting reciprocating engines to sail the seas. This is one of two engines for an American battleship of 20,000 tons displacement, designed for a speed of 21 knots and developing 25000 I.H.P. at 125 R.P.M. of the propellers. With such high power and speed lack of effective lubrication at any point might spell disaster. The oil pipes leading the lubricant to the various moving parts can be easily traced.

Reversing Mechanism

The Stephenson double bar link motion is the usual type of mechanism employed for reversing sea-going reciprocating engines, and is provided with linking-up screws for the purpose of changing the point of the cut-off of steam. The link block, the link pins on the bridle rods, and the bearings of the rocker or reversing shaft are usually provided with oil cups of ample size filled with horse hair and fitted with cross wires for hand oiling on account of the intermittent operation. As there is little motion at these points the tendency of the oiler may be to overlook them, but especially should the link block be regularly inspected and lubricated to prevent wear occurring on the composition gibs between which the link

moves. Link blocks frequently run at rather high temperatures because of steam and hot water leakage past the valve stem packing. The reserve shaft bearings usually have compression grease cups. The reversing engine for operating the reverse gear is usually bolted to one of the back columns of the engine and has floating links and levers controlled from the starting platform. The cylinders of the reversing engine are lubricated by swabbing the piston rod when operation is required.

Hand Oiling

Hand oiling is sometimes employed exclusively on such steam engine bearings which have very limited motion and small bearing loads. It is frequently used for valve and governor mechanisms, for slow speed rocker arms, link motion and the like. Hand oiling also supplements the regular gravity oiling system when the oiler makes his periodic half hour rounds. It is also a practice on some ships to give the oil cups on top and bottom ends of connecting rods, links, eccentric gear, etc., a shot of fresh water when hand oiling on alternate half hour rounds. This produces in the bearing itself the emulsion previously referred to and it will be observed working out of the main journals and on the side of connecting rod brasses. Not only is this lather very desirable, but the addition of water develops a film that greatly reduces the consumption of lubricating oil.

Forced Feed

While not frequently employed on merchant ships, forced feed lubrication is often found on naval reciprocating engines, and is, in fact, a necessity for fast turning propellers where the usual systems are wholly inadequate. With such installations all working parts of the main engine except the valve gear, but including the thrust bearings, are served in this manner. Each engine is usually fitted with its own individual pumping system. The entire engine is enclosed in a sheet steel casing to prevent splashing and waste of oil which also makes possible the return of the used lubricant to the filter and service tank.

Water Cooling Service

Water cooling service by the use of water from the sea is provided for the main bearings, crank pins and eccentrics. This consists of perforated pipes at each side of the crank pins and a connection to each of the crosshead guides. A connection is also made to the thrust bearing, and a pipe is led through the shaft alley with connections to each line shaft bearing.

INTERNAL LUBRICATION

An oil for internal steam engine lubrication must:

(1) Blend thoroughly with the steam.
(2) Adhere to wet surfaces under conditions of scraping, high temperature, pressure and steam velocity.
(3) Lubricate steel and iron surfaces, which surfaces must necessarily fit tightly in order to be proof against steam leakage.

The conditions of lubrication of the interior of the steam engines of the early days, differed but little from those of the present day, excepting that in the earlier days, the speeds were less, the pressures lower and the steam wetter.

It was not long after the introduction of the steam engine, that the engineer discovered tallow was an excellent lubricant for the interior parts. Tallow, however, possessed the one great objection of generating free fatty acid when it came in contact with live steam, which acid would in time score the metal and necessitate new valves, or a rebored or new cylinder. Some few engineers even preferred to obtain butcher's suet, render it themselves and use it for cylinder lubrication. It was proven, however, that suet was inferior to tallow as a lubricant, though it generated less fatty acid and, therefore, was less injurious to the metal parts.

In the early stages of the petroleum industry cylinder oils were largely composed of tallow, ranging as high as 50 per cent. Both the tallow and the original petroleum cylinder oils were fed wastefully through the old-fashioned tallow cup. The introduction of the hydrostatic sight feed lubricator has greatly assisted the use of modern free-flowing cylinder oils.

With steam cylinder lubrication, the lubricant must blend with the steam and, thus blended, adhere to the wet surfaces. If the cylinder lubricant did not blend with the steam the drops of lubricating oil would pass through the cylinder and out the exhaust, probably without coming in contact with the surfaces to be lubricated. The chance of the oil adhering in a drop form under the stress of scraping, steam pressure and velocity, would be infinitesimal. Cylinder oils must, therefore, be thoroughly vaporized or diffused by the steam.

On vessels employing surface condensers, it is necessary that the cylinder lubricant be a straight mineral oil. For saturated steam conditions it has been found that an oil of 130-137 seconds viscosity at 210 degrees Fahr., Saybolt Universal, is most satisfactory.

METHODS OF APPLYING INTERNAL LUBRICANTS

Internal or cylinder lubrication of reciprocating engines is accomplished by a variety of

methods—hand oiling, tallow cups, hydrostatic lubrication and mechanical forced feed devices.

Hand pumps are frequently installed for use when starting an engine or when there is a tendency for internal parts to squeak. The hand pump must always be used with careful judgment as with this method more oil than is required may be pumped into the engine. The usual result is that the excess finds its way into the condenser with the exhaust steam.

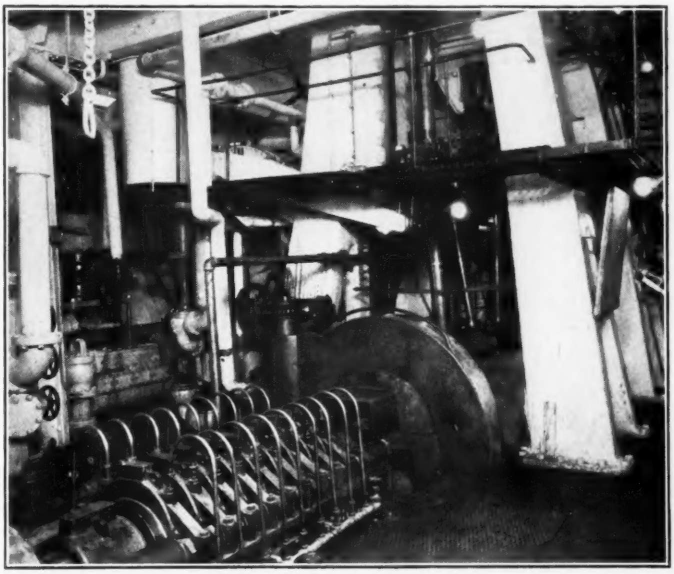
The inefficiency of oil cups as a method of cylinder lubrication is evident. The cup is filled, the cover replaced, the cock at the base opened and the oil permitted to flow into the cylinder or steam chest. This system lacks regularity, results in a waste of lubricant and demands frequent attention.

With hand swabbing, using cylinder oil, the rods and packing are well lubricated but this method is hardly satisfactory for cylinder and valve lubrication. The practice of swabbing rods requires regularity and only with an oil of absolute quality will the lubrication of an engine by this method be satisfactory.

Such an oil must have great spreading ability, the properties necessary for maintaining a lubricating and sealing oil film under high pressure and temperature; also the ability to resist the washing effect of cylinder condensation, the quality to furnish maximum lubrication with a small supply, non-carbonizing tendencies, and the ability to separate quickly from condensed steam in order to avoid boiler troubles. If oil of proper quality were introduced into the steam line by means of a mechanical force feed lubricator in quantities much smaller than those required for the inefficient hand swabbing method, proper lubrication of all parts would be assured without danger of introducing any oil into the boilers.

The hydrostatic lubricator is connected to the main steam line and depends for its action on the replacement of oil with condensate from the steam line. This type of lubricator must be started and stopped by hand. It is not absolutely regular or uniform in its delivery of oil, as changes in temperature, leakage or an obstruction in the delivery passage alter the rate of feed. It must be kept under observation to insure good results.

Force feed lubrication is accomplished by the use of a mechanical lubricator, consisting of an oil reservoir and a small plunger pump for each oil feed, operated by a lever and ratchet motion which is attached to some moving part of the engine. There is a sight feed glass by which the rate of feed may be observed. There is also some means by which the stroke of each plunger may be regulated to increase or decrease the feed. When a good type of mechanical lubricator is selected, this method of lubrication is automatic and absolutely regular in its delivery of oil. The stroke may be adjusted to deliver the desired quantity of oil and by trial a very high degree of economy can be attained. Temperature changes do not influence the feed of a good mechanical lubricator.



Courtesy of The Marine News.

Fig. 5—View of an engine room of a 3000 I.H.P. triple-expansion marine installation. A nine collar horse shoe type thrust is employed, as shown in the foreground, together with its lubricating oil boxes and water cooling pipes. The main crank pins receive their oil through pipes attached to the connecting rod which are supplied from cups secured to the crosshead. The steam jacking gear attached to the after port Y column is shown on the left below the beam operating the air, fire and bilge pumps off the low pressure engine.

HORIZONTAL ENGINES

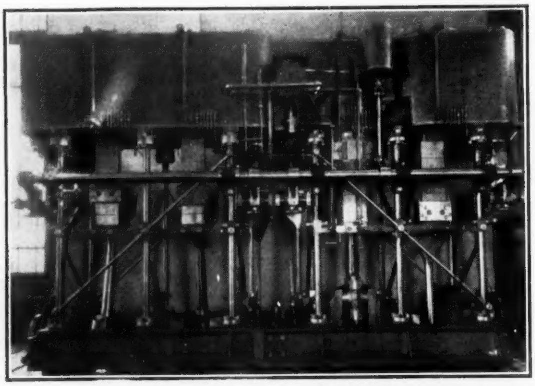
Although horizontal engines are rapidly disappearing, they are still employed on harbor and river craft. Their cylinder lubrication involves a somewhat more intensive problem than do vertical engines. In a horizontal cylinder, except where tail rods are used, the weight of the piston, rings and part of the weight of the piston rod must be borne by the lower portion of the cylinder. On account of this weight the piston will frequently tend to wear the bottom of the cylinder out of round, and unless sufficient lubrication is provided, the clearance between the piston and the cylinder may become so great as to cause serious leakage of the steam past the piston. This increases the

pressure to which the oil film is subjected and may weaken or entirely destroy it.

If the rings become worn and sharp on the edges they will scrape the oil film off the surface of the cylinder walls, to further increase the friction and wear. Because of these conditions the cylinder oil must have the characteristics which will provide a heavy film of oil and must be used in sufficient quantities to maintain it. Even with the most efficient oil a certain amount of wear will take place and rings will have to be renewed occasionally.

Tail Rod Supports an Advantage

Engines having heavy pistons and rods are, therefore, usually provided with tail-rod supports, which, together with the crosshead, carry the weight of the former. In such engines the only pressure on the cylinder walls is that carried by the tension of the piston rings, and a thinner film of oil and a lesser quantity of lubricant are required.



Courtesy of Bethlehem Shipbuilding Corporation, Ltd.

Fig. 6—A cylindrical column type of four-cylinder triple-expansion marine engine developing 1200 I.H.P. at 200 R.P.M. Ease of accessibility to all parts requiring lubrication is a feature of this fast-running machine. The usual conventional method of sight feed drip is employed and the lubricating pipes are clearly indicated.

VERTICAL ENGINES

Vertical cylinders, on the other hand, are comparatively simple to lubricate as the weight of the piston, piston rod, crosshead and connecting rod are carried by the crank pin. The only pressures on the cylinder walls are those due to the tension of the piston rings and possibly to some slight pressure from any side motion which the piston may have.

The rings, no matter of what design, should be accurately set, and just tight enough to prevent any abnormal steam leakage. A film of oil thick enough to prevent excessive friction between these rings and the cylinder walls, and enough oil to maintain this film, are all that is required to provide proper lubrication.

Vertical Marine Engine Cylinders Frequently Not Lubricated

In the vertical marine engine where the condensed steam is used as make-up boiler feed, wherever adequate oil separation may be impracticable, it will frequently be advisable to run without any cylinder lubrication, on the assumption that the amount of water present in the steam will afford the necessary lubrication.

The space rings and piston usually have water grooves to hold a small amount of condensed steam which serves to decrease steam leakage, making it possible to use looser fitting rings and consequently decreasing the friction. After a short time, these cylinder walls become highly polished and glazed, so that the actual friction is lessened.

PISTON AND VALVE RODS

Piston rods, tail-rods, and valve stems to operate effectively require quite as efficient lubrication as valve seats and cylinder walls. While it is usually considered the duty of a cylinder oil to lubricate these latter, it must not be forgotten that detrimental results may occur if they are neglected. It must be remembered that both valve and piston rods are very accurately machined and adjusted; therefore, any overheating due to lack of lubrication might cause a change in alignment, with ultimate damage to the internal mechanism of the engine. The practice of automatically oiling piston rods and valve stems has not been regarded with favor by many engineers, inasmuch as the lighter oils, such as are used in overhead reservoirs for the other running parts, are almost worthless on hot rods. An occasional swabbing with thick cylinder oil prepared for such service will, in most cases, suffice to prevent undue heating.

INFLUENCE OF VALVE DESIGN

In the lubrication of reciprocating engines steam valve design is a decided factor. The two types of valves usually met with are the single-ported and the double-ported slide valves, and inside type and outside type piston valves.

The Slide or "D" Valve

The common slide valve is one of the most difficult to lubricate due to inequalities of pressure and the consequent "wiping" action which it exerts upon the lubricated valve seat. Therefore, where a lubricant is applied, the oil film must be continuously renewed, otherwise ineffectual lubrication may result, with cut or worn valves and seats. The above can normally be detected by the jerky motion of the valve stem which is caused by momentary sticking of the valve to the seat.

The Piston Valve

With the piston valve, on the other hand, the steam pressure is balanced, and as a result there is less tendency for the oil to be squeezed or wiped from the valve seat. As a result, piston valve engines can operate under considerably higher pressures than certain other types of engines.

Where superheated steam is employed, or even high degree saturated steam, inside piston valves are installed whereby the high temperatures are confined between the upper and lower valve faces, thus relieving the valve stem packing.

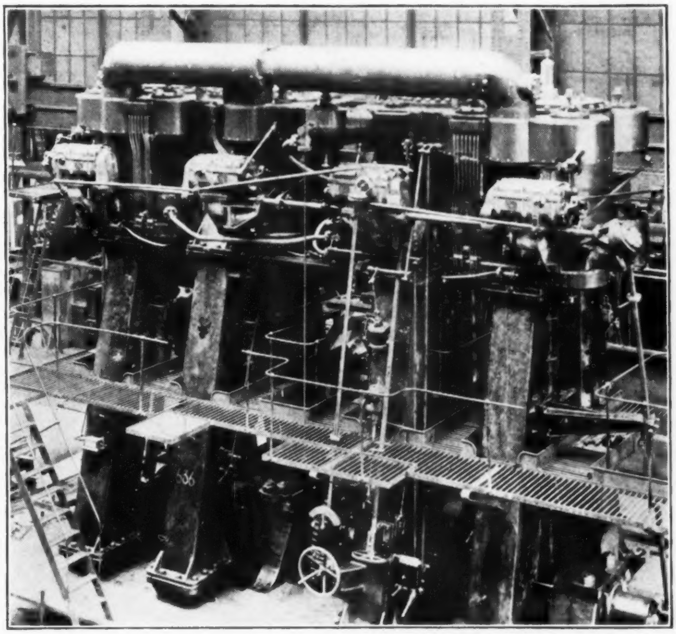
Equilibrium Piston

The work of moving a heavy steam valve up and down puts a large amount of work on the eccentric and is the reason why many eccentrics run hot. It is often a practice to have an assistant cylinder, located on the top of the chest. This cylinder, in which is fitted an equilibrium piston, is open at the bottom to the valve chest, and hence the full pressure of the steam in the chest acts constantly on the lower side of the piston. This may be so proportioned as to carry practically all the direct weight of the valve, which thus floats on the steam, requiring comparatively small effort on the part of the eccentric to move it up and down.

CONDITION OF WEARING SURFACES

In general, the real test of a cylinder oil should be the condition of the wearing surfaces upon which it is used. A hasty decision as to the suitability of such an oil should be guarded against, as time is necessary for the lubricating film to form and function properly. Any test should, therefore, cover a reasonable period of time. When the vessel is in port and opportunity is available to remove the cylinder heads and valve chest covers, the interiors should be examined.

If, upon immediate inspection, the wearing surfaces show a film of lubricant sufficient to penetrate and leave a brownish stain on three or four thicknesses of cigarette paper the former may safely be regarded as being sufficiently lubricated. If below this film they appear highly polished and of a color varying from bright iron-white to steel-blue they have been properly lubricated.



Courtesy of Barclay, Curle & Co., Ltd.

Fig. 7—A four-crank, balanced triple-expansion marine engine, fitted with double-beat poppet type admission and exhaust valves actuated by Caprotti valve gear. This engine has cylinders $23\frac{1}{2}''$ x $40''$ x $50''$ x $50''$ and $48''$ stroke, the high pressure and the intermediate pressure cylinders being arranged in the center with the two low pressure cylinders to the outside, an arrangement giving good balance. The lubricating systems for the moving parts are readily discernible.

Where the surfaces are rough, dry, dull in appearance or rusty, lubrication has either been insufficient or the wrong grade of oil has been used. In addition, if the stain on the cigarette papers appear streaked, blackish or mottled, either the oil has been subject to carbonization or abnormal wear has taken place.

Lack of lubrication will also sometimes be evinced when the engine is running, by sticky valves or groaning sounds from the cylinder.

SUPERHEATED STEAM CONDITIONS

The use of superheated steam has decided economical advantages in marine service. Superheated steam does not condense until its temperature has been reduced to that of saturated steam at the same pressure. Also it has a greater volume per unit of weight than saturated steam at the same pressure, the volume increasing with the temperature.

It has been explained how an engine cylinder operating with saturated steam will eventually acquire what is known as a "water polish." This water polish acts as a protecting film and has a very low coefficient of friction. Where superheated steam is used, however, moisture is not always present. It is a fact nevertheless, that only in few cases where very high superheat is employed, is there any superheat in the steam at the end of the expansion

stroke or throughout the entire exhaust stroke. It is believed that in the neighborhood of 200 degrees Fahr., initial superheat at the throttle is required for any superheat to remain in the steam at exhaust when operating at about $\frac{1}{4}$ stroke. This means that practically all engines using superheat are operated on saturated steam for a portion of their expansion stroke and through the entire exhaust stroke.

Consequently, instead of a purely superheated steam condition, there is a dual problem presented in the selection of the most suitable steam cylinder oil, viz., initial superheat with subsequent saturation or moisture conditions. The one oil must, however, be capable of meeting both services.

If there is not more than about 30 to 50 degrees of superheat, internal lubrication is sometimes effected by injecting a small amount of fresh water with the steam. This water serves the same purpose as the moisture in saturated steam. For superheat of a higher degree, however, it is necessary to use an especially manufactured lubricant for the cylinders. Such an oil must not break down at a temperature as high as 700 degrees Fahr. In order to obtain efficient internal lubrication, the oil must possess the necessary qualifications to maintain a lubricating oil film under the influence of high temperature and steam condensation, and it must be properly atomized and distributed by the steam to the valve seats and cylinder walls.

It is generally impractical to use superheated steam in the auxiliaries due to the difficulty in effecting proper internal lubrication in the cylinders. The steam line supplying all auxiliaries is, therefore, usually installed taking saturated steam from the boiler before it enters the superheater.

Effect of Over-Lubrication

The excessive oil feeds which many engineers have considered necessary for superheated steam cylinders, are due to the use of a straight mineral cylinder oil of high viscosity, and high flash and fire. This straight mineral oil, i. e., a cylinder oil without compounding, while suitable for the lubrication of the cylinder, so long as the steam remains dry or superheated, is not suitable for the lubrication of the cylinder during that portion of the stroke when the steam is saturated, as the moisture washes the oil off the cylinder walls and the cylinder becomes dry. This results in wear and increased friction. Consequently the engineer will be prone to increase the amount fed, so that satisfactory lubrication may be secured, but in doing so, such a large amount of oil is fed to the cylinders that it is not carried away, and accumulations and carbon deposits will result.

In the lubrication of superheated steam cylinders most of the trouble encountered has been caused by this carbonization of the oil, and deposits on the valves at the end of the valve travel and at the end of the counterbore in the cylinders. The carbonization is caused by the oil remaining in contact with the hot surfaces and the superheated steam, long enough for its lighter constituents to be evaporated and the oil partially decomposed. If the oil were of such characteristics that it evaporated more readily and if it were fed to the cylinders in such small quantities that an accumulation of the oil would not be made on the valves and other parts of the engine, the carbon deposits could be entirely eliminated.

PROPER GRADE OF LUBRICANT IMPORTANT

If condensation was not prevalent in a steam cylinder there would be no necessity for requiring a lubricant which would emulsify, and a straight mineral oil would be perfectly satisfactory. In multiple-expansion engines, especially where a low degree of superheat is used in the high-pressure cylinder, the exhaust from the intermediate-pressure cylinder will be relatively wet steam and the proper oil film will not be maintained.

The proper oil for a superheated steam cylinder has a viscosity of about 185-195 seconds Saybolt Universal at 210 degrees Fahr., and a low percentage of animal compound. Such an oil, on account of the compounding, will emulsify slightly and thereby lubricate the cylinders very efficiently during that period when they are filled with saturated steam. As the compounding is small there will be no bad effects resulting from the exposure of the oil to superheat conditions.

An approved type of lubricator should be used for applying internal lubrication where high superheated steam is employed. The mechanical lubricator which works off the main engine is generally most economical and dependable. Where a hydrostatic type of lubricator is used the cylinder oil should be thoroughly mixed with saturated steam previous to its admission in the main steam pipe, to prevent carbonization. Such steam can be taken from a convenient location on the saturated side of the superheater provided a difference in head of about two feet is available to mix the steam and oil. The mixture of steam and oil is then carried in globular form into the main steam pipe and thence to the high pressure cylinder. While the amount of oil required will vary according to conditions, it is figured that approximately one pint per thousand horse power per twenty-four hours should be sufficient to secure an efficient oil film between the working surfaces of the piston and the piston valve.

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